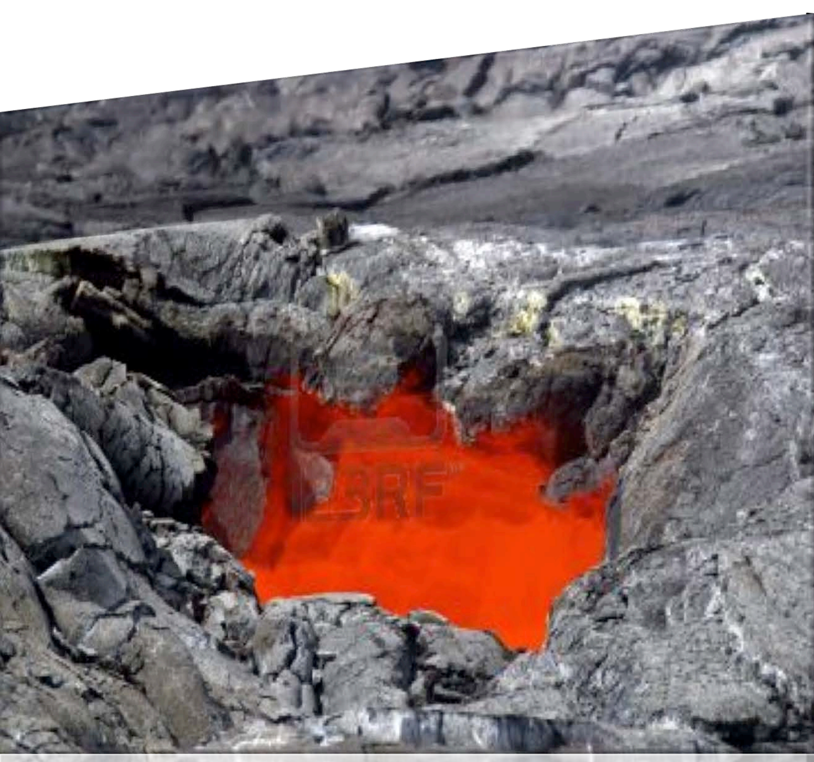
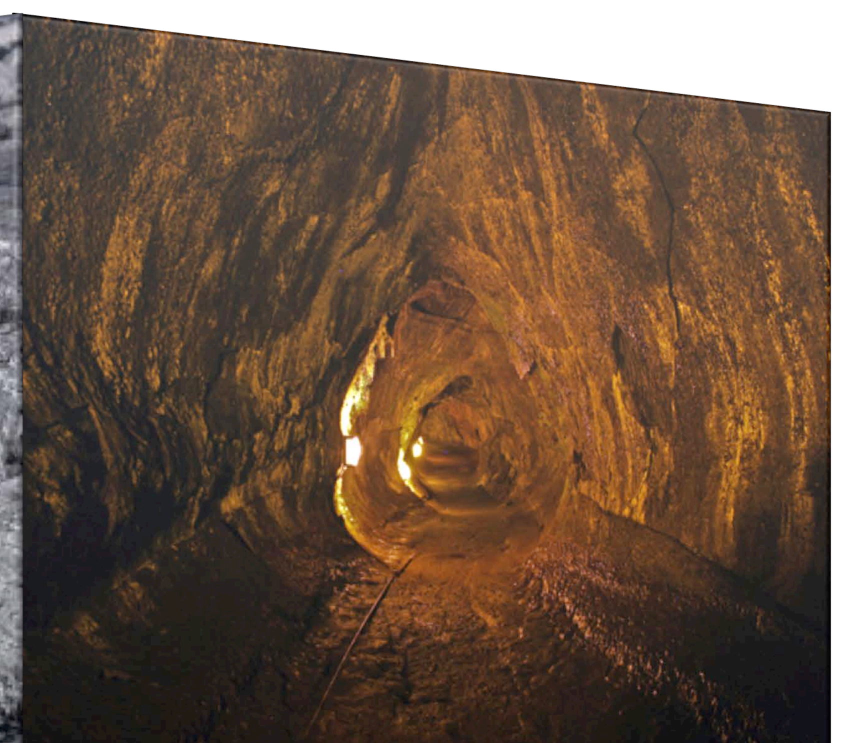
Collaborative Robotics with Space Applications

Abstract

The focus of this project is theoretical research into applications for collaborative robotics in space and the simulation of the missions in a simplified environment utilizing equipment available at Stevens Institute of Technology. Mission profiles for collaborative robotics covered in this project include rescue and recovery missions as well as Lava Tube exploration missions. The simulations of collaborative robotics systems using Stevens equipment utilize two robot systems that communicate with each other via a tethered connection. The robots in each of the simulations are in a leader/follower setup, where one robot is responding to assist the other. The first two profiles to be tested are rescue/recovery and payload transfer. Additional profiles to be tested will be determined once these mission profiles have been refined in simulation. The programs developed for the simulations can later be modified for full-scale testing with minimal effort.

Lava Tubes


Skylight above an active Hawaiian lava tube


Interior of Thurston Lava Tube

Lava tubes are geological features which form as a result of volcanic activity. Over time, a volcano builds up pressure, and one way that this pressure can be relieved is by causing lava to flow out. When lava flows underground away from a volcano, it forms a tunnel. This tunnel is a lava tube. When the lava tube forms close to the surface, the ceiling is not always strong enough to support the ground above and that area of the ceiling collapses on itself. The opening caused by this collapse is referred to as a skylight.

Just like on Earth, in space scientists suspect that where volcanoes were once active, there are likely to be lava tubes. In addition to storing geological history like on Earth, lava tubes in space have advantages that astronauts seeking to utilize the land. Because lava tubes are located underground, lava tubes proved empty cavities that are better protected from temperature fluctuations, micrometeor impacts and radiation. This protection both allows the astronauts to better survive in these environments and to minimize the material necessary to be brought from Earth.

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Goddard Institute for Space Studies
New York City Research Initiative
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Contributors:
Principal Investigators: Dr. Siva Thangam, PhD; Professor Joseph Miles
High School Teacher: William Carroll
Undergraduate Student: Michael Creech

Mission Profiles

Rescue/Recovery

If a piece of equipment fails in a hostile environment, such as space, it is of great risk to send an astronaut or team of astronauts to handle the situation; if something goes wrong for the astronaut team, it creates a second set of problems. Because a robotic team is more expendable, it is advantageous to send robots out for the crisis management. Although eventually a fully autonomous team of robots would be desirable, the immediate future would see tele-robotic teams operated from a safe environment, such as a habitat or Earth-based station. The project simulates this mission profile with a robot responding to a distress call from another robot.

Exploration and Mapping inside Lava Tubes

Lava tubes are a risky environment for a human crew to go into without knowing what lies ahead. To get an idea of what tubes are worth further exploration or human utilization, a robot team can be deployed to map out the lava tube and determine its length, diameter, and hazards. Once this data is analyzed, astronauts and ground crews can determine if the lava tube is safe for use or worth further exploration. This project looks at a robot pair that is designed to work around the difference in terrain of the ground near a lava tube and inside the lava tube. One robot carries the other robot to the lava tube entry site, where the second robot enters the lava tube and maps it out, then is recaptured by the original carrying robot.

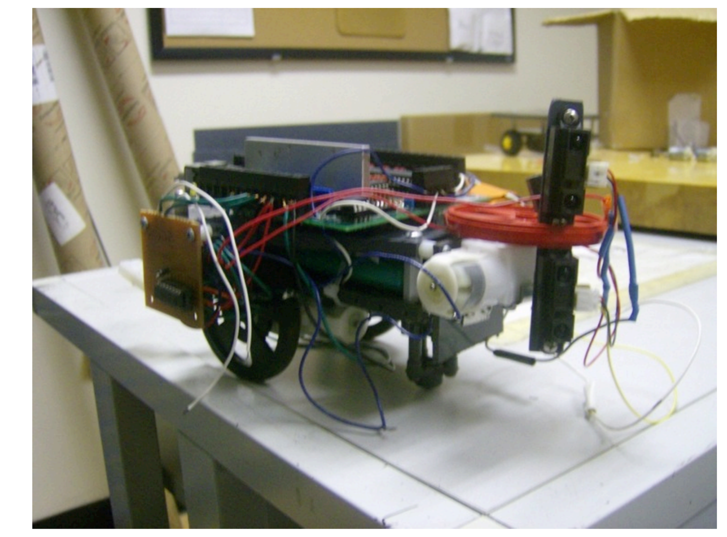
Equipment Deployment inside Lava Tubes

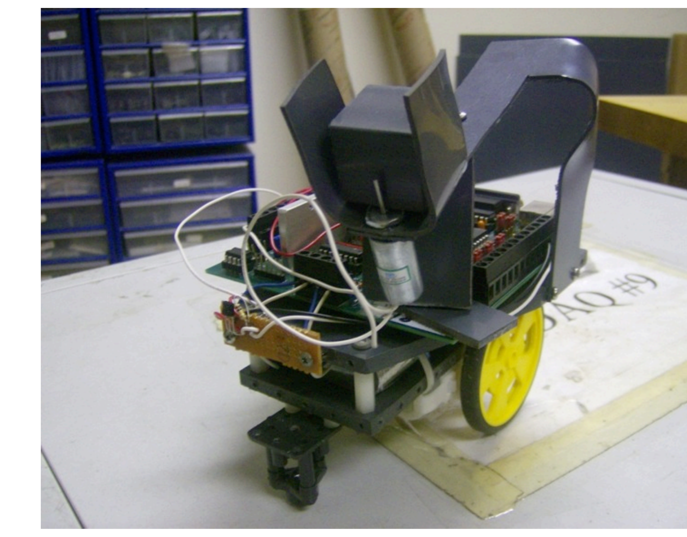
Infrastructure such as habitat modules, nuclear power stations, and cables for power and communication could be stored inside lava tubes. It is much safer to deploy this equipment with robotic teams in the lava tube than it is for astronauts. The design matrix below compares three different types of lunar cable laying mission profiles. All of the designs analyzed assume that a positioning system similar to the Global Positioning System. The first mission profile type is a carrier and runner combination where the robot that enters the lava tube is carried by a robot designed to traverse a rocky surface. The first type is a legged carrier which traverses the rocky terrain to the lava tube entrance, where it lowers itself and deploys the runner at a ground entrance. The second variant is a wheeled crane which lowers the runner once it reaches a skylight. The last solution consists of two identical, legged robots which are used to perform the task faster or to complete the mission if one robot fails. Ultimately the crane and runner combination best met the requirements.

Criteria	Weightings	Carrier/Runner Raw	Carrier/Runner Weighted	**Crane/Runner Raw**	**Crane/Runner Weighted**	Climbers Raw	Climbers Weighted
Mechanical Complexity	20%	5	10.0%	**8**	**16.0%**	2	4.0%
Terrain Versatility	15%	6	9.0%	**5**	**7.5%**	8	12.0%
Risks of Failure	5%	3	1.7%	**4**	**1.3%**	4	1.3%
Likelihood of Failures	8%	5	4.0%	**7**	**5.6%**	3	2.4%
Size	5%	5	2.5%	**3**	**1.5%**	8	4.0%
Software Complexity	12%	7	8.4%	**5**	**6.0%**	2	2.4%
Launch Weight	5%	5	2.5%	**4**	**2.0%**	8	4.0%
Communication	8%	7	5.6%	**8**	**6.4%**	5	4.0%
Availability of Technology	9%	5	4.5%	**8**	**7.2%**	3	2.7%
Stability	7%	5	3.5%	**7**	**4.9%**	2	1.4%
Power Reliability	6%	7	4.2%	**8**	**4.8%**	5	3.0%
Totals	100%	57	55.9%	**63**	**63.2%**	46	41.2%

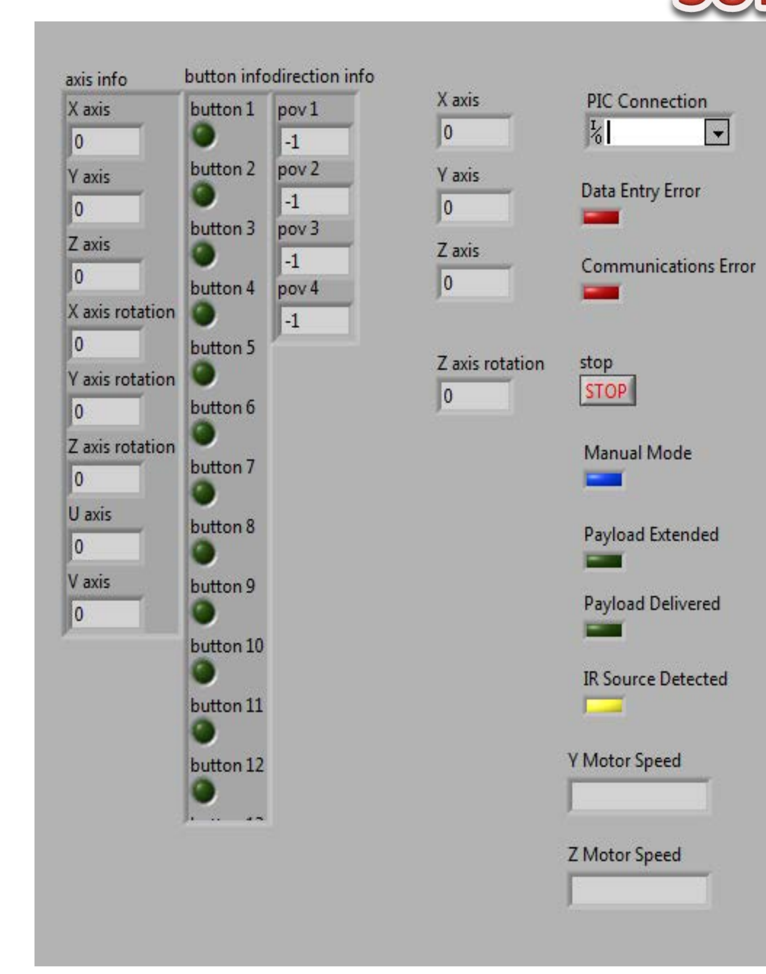
Simulation

Robots Used


Fully Autonomous Unit


Remote Controlled Unit

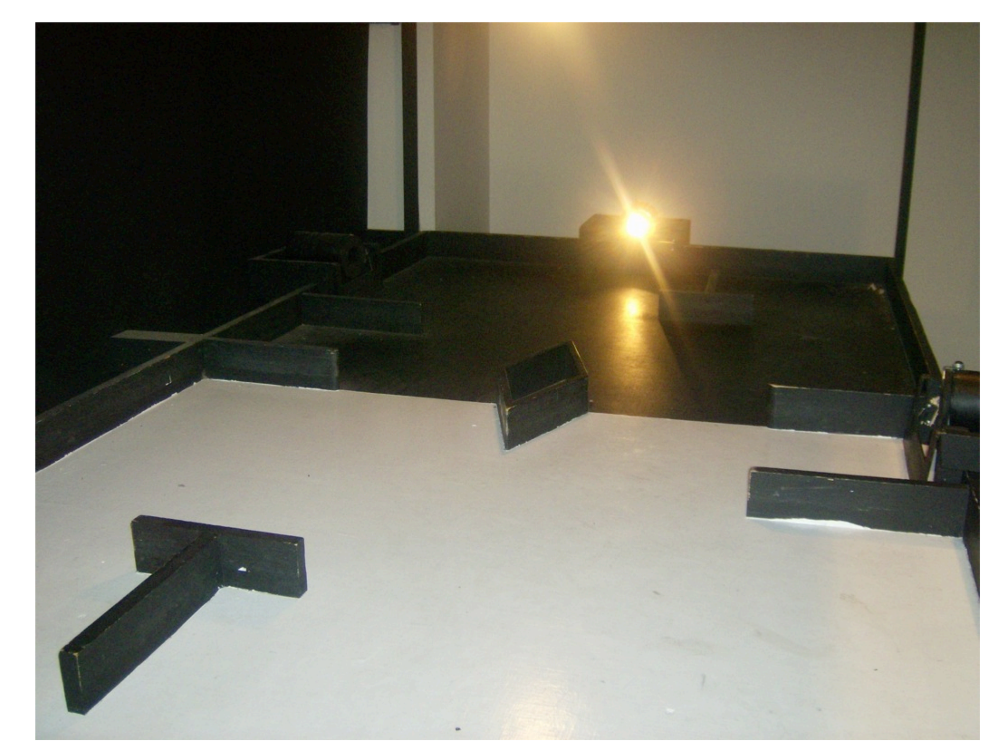
Software


LabView VI for Remote Controlled Unit (RCU)

```
void Forward() //Drives Robot forward assuming small side front
{
    output_high('C',4);
    output_high('C',5);
    output_low('C',0);
    output_low('C',3);
    pause(100);
    return;
}

void Reverse() //Drives Robot backward assuming small side front
{
    output_high('C',0);
    output_high('C',3);
    output_low('C',4);
    output_low('C',5);
    pause(1000);
    return;
}

void Stop() //Stops Robot
{
    output_low('C',0);
    output_low('C',3);
    output_low('C',4);
    output_low('C',5);
    pause(500);
    return;
}

void Pivot_CCW() //Turns Robot CCW
{
    output_high('C',3);
    output_high('C',5);
    output_low('C',0);
    output_low('C',4);
    pause(100);
    output_low('C',3);
    output_low('C',5);
    pause(100);
    return;
}
```

C code for motion subroutines in HI-TIDE Environment

Simulation Field



The purpose of the simulations is to demonstrate the technology being used in a simplified environment with software algorithms that could be easily modified for the lava tube environment. The robots are designed with multiple simulated missions in mind, focusing on the exchange of a two ounce payload between the two robots. One robot is a fully autonomous robot which navigates the course using a pair of proximity sensors to create a low resolution, three dimensional image of the environment in front of the robot. The second robot is a remote controlled robot which is operated via a computer equipped with LabView. The fully autonomous unit simulates the main robot in the missions described on the other side of the poster, whereas the remote controlled unit simulates the assisting robot.

The simulation tested multiple scanning types for the proximity sensors: a progressive scan, which reacts at each data point, and a complete scan which takes all the data points and then reacts. Although the complete scanning method was expected to run a little slower, initial testing yielded the complete scanning method was significantly slower than the progressive scan mapping. The accuracy of the two systems is harder to compare due to a glitch with the array and requires further refinement before the accuracies can truly be evaluated.